"Etiology of Puerperal Fever," in which he divides honors with the great Hungarian obstetrician, Semelweiss. It is said of Goethe that he might have been the greatest scientist of his age had he not chosen to be the greatest poet. The man who made the greatest contribution to medicine in the nineteenth century, Pasteur, was not a physician, but a chemist. Elihu Burritt with his knowledge of many languages was a blacksmith. Virchow, the father of cellular pathology, was a socialistic-democrat, a member of the Reichstag and a vigorous opponent of Bismarck.

Permit me to briefly summarize my chief themes: Education is the modification of behavior through experience. The mechanism of learning consists of the nervous system with its sense receptors, conductors, centers and effectors. Education is secured by opening up neural pathways to the brain; this requires effort, but a frequently traveled path becomes smooth and easy. The course of learning does not show a constant ascent, but has occasional plateaus. Special pathways are needed for the acquisition of special knowledge. A fundamental education should include language, mathematics, history and science. No education can be symmetrical without training in all these. Upon these as foundation stones, the tower of special knowledge may be carried as high as the builder can.

Accuracy and promptness in formulating judgment are the ends sought in education; correctness first, and readiness next. When these qualifications are accompanied by the ability to be both prompt and effective in action the individual becomes of highest service to himself and his fellows.

I am aware of the fact that the advice of age does not meet a ready reception in the mind of youth. The old frequently envy youth its opportunities and wish that they were again young. This is idle and besides is not desirable. My generation has enjoyed great privileges. It has been my personal good fortune to know in the prime of life that great Englishman, the founder of antiseptic surgery, Joseph Lister, to sit at the feet of that great German, the discoverer of the tubercle bacillus, Robert Koch, and to look into the face of that greatest of Frenchmen, the man who laid the foundations of preventive medicine, Louis Pasteur. Were the price offered eternal youth, I would not tear from memory's book one page of its golden lessons, and I ask no higher immortality than that there should be found among my students those who have been inspired by my words and works, to carry forward the torch of science to light their fellow-men on their way to wider knowledge and its beneficent rewards.

Man has already accomplished much, but the greater tasks lie ahead. The productivity of the soil must be increased a hundredfold. Grains and fruits, yet unknown, must be grown. The heavy burdens that still oppress the shoulders of labor must be transferred to the tireless muscles of machinery. The literature of the higher civilization is, as yet, unwritten. Laws for which no precedents can be found must be framed and administered. The giant strength of intra-molecular energy must be harnessed into the service of man. A broader morality must govern our behavior, one to another, and a loftier religion must enthuse the common aspirations of the race. All this and much more must be achieved before man fully develops his highest potential greatness.

The world of effort is before you, young men and women. The road ad astra lies per aspera, but bruised heels and aching limbs count for naught when the way leads upward toward the mountain tops of human growth and perfection. Keep to this road, doing what you can to lift yourself and your fellows to a more rational life, and Michigan will have done well in bestowing upon you her richest gift, an education.

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THE USES FOR MATHEMATICS

MATHEMATICS has been termed the handmaiden of the sciences. Whether or not the mathematician himself accepts this as a truthful representation of his beloved science de-

pends upon what the word "handmaiden" connotes. If it is used to designate a supposed inferiority either in value or respect, or a menial and degrading compulsory service, he justly rebels against the use of this metaphor. If, on the other hand, divested of all suggestion of inferiority ordinarily concomitant with the use of the term servant, the word is only construed to mean a voluntary, honorable assistance, then, though deploring the use of a figure with such possibilities for false interpretation, he may not seriously object to its use. Mathematics undoubtedly does render incalculable aid to the exact and many other sciences.

Since mathematics antedates the other familiar sciences, astronomy excepted, its existence is surely not dependent upon their existence, nor can service to the other sciences be its sole aim and object. It does not live to serve, alone. It is not a born slave. It has an existence absolutely independent of any use to which it may be applied. The mathematician has pursued and will pursue his investigations regardless of material profit. The unselfish motive which directs his activities as well as those of other pure scientists is that love of knowledge pure and simple which seeks no reward other than the intellectual delight incident to the discovery of unknown truth, for him the revelation of hitherto unseen relations existent in the realms of number and space. However abstract and remote from practical application the truth revealed, matters not. He is not and refuses to be guided by mercenary motives.

If, however, in the light of popular conceptions, the standard of appreciation of science be the extent or importance of its application to the exigencies of daily life, mathematics gains rather than suffers from the lowering of the standard. Nevertheless the teacher of mathematics is frequently required by the prospective student to justify the usefulness of his courses. It occurred to me that a very definite and unprejudiced reply to such queries can be obtained from the Encyclopedia Britannica, 11th ed. This great work which is a "survey of the field of knowledge" presumably is impartial. Necessarily only the essentials can be given in such a work. We have selected from this book those subjects which have required the symbols of infinitesimal calculus in their treatment. The list is intended to be complete, but omissions are probable, owing to the haste in covering so many pages. Notice of omissions will be welcomed. Some of the subjects, such as infinitesimal calculus, are obviously mathematical, while the appearance of others, such as clock and sky, may surprise even mathematicians. The list would be far greater if we based it upon a lower subject such as trigonometry instead of calculus.

The list contains 104 headings which are as follows: Aberration, accumulator, æther, algebra, algebraic forms, amplitude, astronomy, atmospheric electricity, aurora polaris, ballistics, bearings, Bessel function, bridge, calculating machine, calorimetry, capillary action, chemical action, chemistry, clock, combinatorial analysis, condensation of gases, conduction electric, conduction of heat, curve, cycloid, differences calculus of, differential equation, diffraction of light, diffusion, dynamics, dynamometer, earth figure of the, elasticity, electrokinetics, electrolysis, electromagnetism, electrostatics, energetics, Fourier's series, function, fusion, geodesy, geometry, gravitation, groups theory of, gyroscope and gyrostat, harmonic analysis, heat, Herbart, hodograph, hydraulics, hydromechanics, illumination, induction coil, infinitesimal calculus, interference of light, interpolation, lens, light, lighting, logarithm, lubrication, magnetism, magnetism terrestrial, magneto optics, map, maxima and minima, mechanics, mensuration, meteorology, molecule, number, power transmission, probability, quaternions, radiation, radioactivity, series, shipbuilding, sky, solution, sound, spectroscopy, spherical harmonics, spiral, steam engine, stereoscope, stoichiometry, strength of materials, sun, surface, surveying, table mathematical, tacheometry, thermodynamics, thermoelectricity, thermometry, tide, time measurement of, transformer, trigonometry, units physical, vaporiza-

tion, variations calculus of, vector analysis, wave.

That mathematics is the handmaiden of the sciences is fully confirmed. Only about a fourth of the headings are those of pure mathematics. The wide variation of the subjects is evident. They cover the subjects of five sections of the American Association for the Advancement of Science.

If these facts are pointed out to the students, it will doubtless give them a greater interest in the subjects of mathematics, for even though they can not understand the references they can at least grasp their significance and approach their work with a conviction that it is worth while. It is hoped that this list may prove valuable to teachers in this way.

The student should appreciate early the importance of his mathematical training in his work, particularly in any subject of exact science. The haste made necessary by the limitations of time and the demand for more and more principles leaves little time for the application of known principles to explain nature in a mathematics class. The utility of the subject may thus not be as obvious to the inexperienced pupil as to the teacher. The subject of mathematics should not be considered by the pupil as mere continued drudgery without ultimate gain. When those uninspiring successions of hooks and crooks are clothed with a garb of meaning provided by nature herself and their real import and significance made manifest, they command a proper reverence because of that which they have accomplished. The beauty of the truth revealed or explained sheds a sense of beauty even over the cold abstract reasoning.

The student should know that that which he dimly foresees will appear before him as a panorama of extended beauty over which he can roam when once he has mastered that most wonderful and powerful instrument of modern analysis, discovered by Newton and Leibnitz, and so fully developed and applied by that constellation of immortal mathematicians the Bernouillis, Clairaut, Euler, Lagrange and Laplace, namely the infinitesimal calculus. He will then have a deeper insight into, and a partial comprehension of the plan of nature. Beauty concealed by ignorance of the mathematics necessary for interpretation will be revealed to him. He will then see that of which the untutored mind has no conception because lying beyond its comprehension.

The massive bridge once wonderful because of its enormous size, when its principles of construction are understood becomes a thing of beauty, a wonderful monument to the intellect of the designer and constructor. The great tunnels, turbines, subways are changed to objects of wonder to those who are capable of understanding the difficulties overcome in their construction. The stars in the universe above which nightly dissipate some of their light upon the earth bespeak their Creator's glory in voices but faintly heard by those whose training does not enable them to comprehend the reign of law there prevailing. To such an one the heavens declare the glory of God in a more real and exalted sense. The earth is full of His glory. There will be "sermons in stones."

The extent to which natural laws have been discovered and expressed in mathematical equations must be a source of unending wonder. "Order is heaven's first law." The mathematical equation is the apotheosis of order. It will ever be a matter of self-congratulation to mankind that they can thus interpret natural phenomena by expressing the inexorable laws governing them in equations. We should better say that we are thankful to God for revealing to us those laws to which He has subjected His creation. It must compel a higher order of admiration for the Creator that He has made things thus.

One of nature's demands in which she is inexorable is a study of higher, the highest mathematics. The interpretation of her laws requires it. I close by quoting a scientist of wide fame. Sir John Herschel in the introduction to his celebrated "Outlines of Astronomy" writes:

> The utmost pretension of this work is to place its readers on the threshold of this particular wing of science, or rather on an eminence exterior to it,

whence they may obtain a general notion of its structure. . . . *Admission to its sanctuary and to the privileges and feelings of a votary is only to be gained by one means—sound and sufficient knowledge of mathematics, the great instrument of all exact inquiry, without which no man can ever make such advances in this or in any other of the higher departments of science as can entitle him to form an independent opinion on any subject of discussion within their range.*

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THE LATE WILLIAM SAUNDERS, C.M.G., LL.D.

In the death of Dr. William Saunders, C.M.G., late director of the Dominion Experimental Farms, which took place at London, Ontario, on September 13, there passed away a notable pioneer in the field of Canadian agricultural investigation, one who had worked hard and successfully in the best interests of his country for more than a quarter of a century and who, we rejoice to say, had lived to see in a large measure the fruits of his labor in a very material improvement of our basic industry, in methods, in crops and in stock throughout the length and breadth of the land. Comparing the agriculture of this country to-day with that of 1886, when Dr. Saunders entered upon what we may term his life work—the establishment of the Experimental Farm System—it is abundantly apparent that farming in all its branches has developed and prospered and we can not doubt that the varied activities of this system, in research and in the wide dissemination of information among our farmers, carried forward as they have been by Dr. Saunders and his co-workers with enthusiasm and skill, must have played a very important part in this agricultural progress. It has been a valuable and national work, and stands to-day as a monument to the initiative, the unflagging zeal and the untiring energy of Dr. Saunders, who held the directorship of the farms from their establishment to April, 1911, when he retired, owing to failing health and advancing years.

William Saunders was born in Devonshire, England, in 1836, and came at the age of 12 years to this country with his parents, who settled in London, Ontario. In early manhood he studied chemistry and pharmacy and subsequently established a business for the manufacture of pharmaceutical preparations, a business which he successfully carried on till 1886, when it was handed over to his eldest son, William E., who has remained since that date as head of the firm. In 1882, we find that his chemical knowledge had gained for him the post of public analyst for Western Ontario. Previous to that date he had taken a leading part in the founding of the Ontario College of Pharmacy, of which he was president for two years. He was also on the professoriate of the medical faculty of the Western University. His interest in entomology led him to assist in establishing the Entomological Society of Ontario, of which he was president for the period 1883–6. In the practical work of this society he maintained an active and warm interest throughout his life, acting as editor of its organ, the *Canadian Entomologist,* for thirteen years. As a result of his entomological studies, which were mainly of an economic character, he published in 1882 his work entitled "Insects Injurious to Fruit," a book that has been widely used as a text in agricultural colleges and by orchardists in the United States and Canada.

In 1868 Dr. Saunders purchased a small farm in the neighborhood of London and there, it may be said, he laid the foundation of his future work in horticulture, always his favorite study. This area of land, which he planted largely to fruit, enabled him to investigate and observe in the fields of experimental agriculture and horticulture, and no doubt furnished him with those qualities and that knowledge which led to his selection as the one best qualified to undertake the important task of establishing the Experimental Farm system. His many successes in the production of new fruits, flowers and grains during this period testify to his skill as an hybridist of the first rank.

Of his work as head of the Experimental Farms it will only be possible to give the